

A BRIEF HISTORY OF PEOPLE AND EVENTS RELATED TO ATOMIC WEAPONS TESTING IN THE MARSHALL ISLANDS

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Abstract—The events related to nuclear testing in the Marshall Islands began at the end of WWII when the U.S. began an initiative to determine the effect of nuclear weapons on naval vessels and on the performance of military personnel. The first tests took place in 1946 even though the area known as Micronesia was not entrusted to the U.S. by the United Nations until 1947. Beginning with the first relocation of the Bikini people to Rongerik Atoll in 1946, the saga of the Marshall Islands involvement in the atomic age began. Although the testing program was limited to the years 1946 through 1958, many of the consequences and events related to the testing program continued over the decades since. That story is still ongoing with programs currently underway to attempt to resettle previously displaced communities, remediate contaminated islands, and to settle claims of damages to individuals and communities. The history of the years subsequent to 1958 are a mixed chronicle of a few original scientific investigations aimed at understanding the coral atoll environment, continued surveillance of the acutely exposed Marshallese, some efforts at cleanup and remediation, numerous monitoring programs and many studies repeated either for credibility purposes, to satisfy international demands or because the changing state of knowledge of radiation protection has necessitated us to rethink earlier beliefs and conclusions about late health effects and social consequences. The objective of this paper is to briefly note many of the historical and political events, scientific studies, persons and publications from 1946 to the present that relate to atomic weapons testing in the Marshall Islands.

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INTRODUCTION

THE MELDING of the history of the Marshall Islands and the United States began at the end of WWII when the U.S. Navy began an initiative to determine the effect of atomic weapons on naval vessels and the performance of military personnel. Beginning under the Truman administration and continuing under Eisenhower, the enthusiasm of

the U.S. government for testing new and larger atomic weapons was apparently a sign of post-war uneasiness, partially a result of advances in nuclear technology by our Soviet counterparts. The 1950's was the period of Mutual Assured Destruction (MAD[†]), when the East and West manufactured 50,000 nuclear and thermonuclear weapons. During those years, children in the U.S. were taught to plunge under school desks at the sound of an air-raid siren, and their parents were encouraged to build fallout shelters. The nuclear rivalry during those years and the anxiety that accompanied it ultimately led the U.S. to involve the remote mid-Pacific islands (Marshall Islands, Johnston Atoll, and Christmas Island) in the blossoming nuclear age.

The technical programs as well as the administration of the U.S. atomic weapons testing program in the Marshall Islands is recorded in many thousands of historical military and government documents, but little historical narrative of the events related to the testing program has been written. MSC (1978) and Deines et al. (1991) provide substantial summary information in chronological order and may be consulted by interested readers. At least one early book (Hines 1962) concentrated on discussing scientific studies in the Pacific that were conducted during the testing years. Schultz and Schultz (1991) provided a bibliography of government related documents to atomic testing in the Marshall Islands while Stannard (1988) reviewed in general the era of testing and the exposure of the Marshallese from BRAVO. Eisenbud (1990) gave a fascinating account of events, mainly during the 1954 CASTLE series, from the point of view of the director of the AEC Health and Safety Laboratory. Several of the above publications are not easily obtainable and none include developments over the last 5 y.

The objective of this paper is to provide a short overall synthesis of events and medical and environmental consequences and to note some of the people involved and important publications related to the atomic weapons testing program in the Marshall Islands. The literature sources mentioned above were drawn upon as were numerous scientific reports from past and present U.S. agencies, historical memoranda from archives, as well as events witnessed by the author during the last 7 y. No attempt is made to list all available publications, rather a cross-section of important documents is given. Some

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[†] See Table 1 for a list of all acronyms used in text.

emphasis is given to the BRAVO incident because of its notable importance to later day consequences. This chronology covers the history to the present date.

HISTORY OF THE MARSHALL ISLANDS: PRE-ATOMIC TESTING ERA

2000 B.C. to 1500's

The small islands of the mid-Pacific, later to be known as Micronesia, were discovered by canoe-traveling seafarers from western Melanesia or southeast Asia. Parent communities spawned other communities at distances that could be covered by canoe, sometimes up to hundreds of km distance. This prehistoric movement across the Pacific resulted in the eventual migration and colonization of Oceania (Bellwood 1979), including the area now known as the Marshall Islands.

1600's-1900

The small islands, later to be known as the Marshalls, were discovered by Spanish, Dutch, and English explorers and later Germans. The southern islands of the Marshalls were put to use for gathering coconuts for production of copra oil.

Early 1900's

Japan began an administration of the islands; their domination afforded them the opportunity for military buildup in anticipation of WWII.

THE ATOMIC WEAPONS TESTING ERA

1944

The Marshall Islands, which had been administered by Japan since the end of WWI, fell to the U.S. military forces in bloody battles at Kwajalein and Eniwetak and other atolls during the war in the Pacific. There were about 3,000 U.S. casualties and about 11,000 Japanese casualties in these battles.

1946

In February following the end of WWII, Commodore Ben H. Wyatt, the appointed military governor of the Marshall Islands, asked the people of Bikini if they would leave their atoll temporarily so that the United States could begin testing atomic bombs "for the benefit of all mankind" (Weisgall 1994). In March, the 166 Bikini people were relocated by the U.S. Navy to Rongerik Atoll, about 125 miles east, to make way for preparations for the atomic testing program on Bikini beginning with Operation CROSSROADS. Residents of Eniwetak, Rongelap, and Wotho Atolls were also temporarily relocated during CROSSROADS. The Eniwetak community was moved to Meck Island (Kwajalein), and the communities on Rongelap and Wotho were moved to Lae Atoll.

The spectacle of Operation CROSSROADS, which included the world's third and fourth atomic explosions (ABLE and BAKER), was displayed at Bikini Atoll in June and July under the watchful eye of some 42,000 soldiers, press, politicians, and official spectators. Nearly

100 vessels were used as targets for the tests of CROSSROADS including the US aircraft carrier *Saratoga*, the US battleship *Arkansas*, the Japanese battleship *Nagato*, the German cruiser *Prinz Eugen*, and the Japanese cruiser *Sakawa*.

The Atomic Energy Commission (AEC) was born under the Truman administration by the signing of the Atomic Energy Act in August.

1947

The entire area of Micronesia was designated by the United Nations Security Council as the United Nations Strategic Trust Territory (TT) to be administered by the United States. Truman delegated the administration of the TT temporarily to the U.S. Navy.

The Applied Fisheries Laboratory[‡](AFL) of the University of Washington issued a report on a resurvey of Bikini Atoll conducted in the summer (Donaldson 1947). The studies reported on were a continuation of studies they began immediately following CROSSROADS in 1946.

An investigating board recommended removal of the Bikini people from Rongerik because of insufficient food and water (Deines et al. 1991).

The 145 Eniwetak inhabitants were relocated to Ujelang Atoll to ready Eniwetak Atoll for nuclear testing upon a recommendation of AEC Chairman, D. Lilienthal.

1948

The Bikini people were relocated to Kwajalein Atoll for about 6 mo because of near starvation on Rongerik Atoll. After a lengthy search for a new home, the Bikini people agreed to relocate to Kili Island because of the absence of alternative residence sites, and they were again moved (see Niedenthal, 1997). Kili was viewed as only a temporary home[§] because it lacks a lagoon and protected anchorage, both important for fishing as a means of feeding the community.

Operation SANDSTONE was conducted in April and May at Eniwetak Atoll and included 5 tests. In May, the AFL collected aquatic specimens for study. A second collection was made at Eniwetak in July after the completion of a survey of Bikini.

1949

A report on the Bikini "resurvey," i.e., a second collection of aquatic organisms, was issued by AFL (Donaldson 1949).

1951

Operation GREENHOUSE was conducted in April and May at Eniwetak Atoll and included 4 tests.

[‡] The Applied Fisheries Laboratory had begun in 1944 as part of the Manhattan District program; its name was deliberately made misleading to hide its connection. The name was changed in January 1958 to the Laboratory of Radiation Biology (Hines 1962).

[§] The Bikini people are still resident on Kili Island today.

1952

The Health and Safety Laboratory (HASL, now the DOE Environmental Measurements Laboratory) located within the AEC New York Operations Office was originally assigned to monitor the area in the Marshall Islands beyond 500 miles, leaving the closer islands the responsibility of Joint Task Force 132. In September, however, "the NYOO assignment was extended to include all of the islands of the Trust Territory except Enewetak itself" (Eisenbud 1953a). The monitoring programs that were subsequently developed included 111 gummed film stations worldwide as well as a system for aerial monitoring of the islands in the western Pacific.

In early October, before Operation IVY, the Navy transported 169 Ujelang people 100 miles further away from Enewetak as a precautionary measure.

Operation IVY (2 tests) was conducted in October and November at Eniwetak Atoll; the first test MIKE was the first U.S. thermonuclear weapon detonated. MIKE vaporized the island of Elugelab, which housed the cryogenic plants for maintaining liquid tritium and deuterium. Left in its place was a one-half mile deep crater. In the nuclear debris from MIKE, two new isotopes of plutonium were discovered (^{244}Pu and ^{246}Pu) as well as two new elements, einsteinium and fermium (Seaborg and Loveland 1990). Fortunately, the main fallout debris from MIKE fell onto the open Pacific Ocean as planned (Eisenbud 1990).

1953

Maj. Gen. P. W. Clarkson was appointed military commander for Joint Task Force 7 (JTF7), which had responsibility for the conduct of the CASTLE series.

HASL issued a report on radiological surveys following Operation IVY (Eisenbud 1953b) and began preparations for monitoring Operation CASTLE. It was decided that automatic continuous reading radiation monitors would be installed at Truk, Ponape, and Kusaie (all three in the TT; now the Federated States of Micronesia) and Majuro, Rongerik, and Ujelang (three atolls of the Marshall Islands). The equipment as designed was automatically triggered into operation by an increase in the radiation level from the passing of a radioactive fallout cloud. Power provisions would keep the instrument running from 8 to 10 d, after which it was intended that they would be retrieved. Also planned was the placement of gummed paper on naval vessels in the Pacific (Eisenbud 1953a) to supplement the limited data that could be obtained from island monitoring.

In October, the AEC Weather Bureau office issued a "Meteorological Analysis of the Transport of Debris from Operation IVY" (Hubert et al. 1953).

A report (Lulejian 1953) was issued by the Air Research and Development Command in November to evaluate the long range hazards of radioactive fallout. The report was immediately classified and recalled soon after distribution (statement of M. Eisenbud, Congress 1994).^{||} The report predicted for the first time that lethal

concentrations of radioactivity may extend 30–50 miles downwind of the detonation site of 10 megaton weapons. Furthermore, it predicted high concentrations of radioactivity over an elliptical area of 1,000–5,000 square miles.

Maj. Gen. Clarkson determined that pre-shot evacuation of inhabited atolls would not be necessary for CASTLE because wind conditions prior to the test would be used to judge the safety of the pending tests. HASL recommended a standby evacuation plan for Marshallese in case of unexpected fallout on inhabited atolls but the suggestion was not accepted by JTF7 (Eisenbud 1990).

The AFL reported on tumors on *Ipomoea tuba* plants (a ground vine) at Enjebi Island, Eniwetak, sampled during July and August 1949, 17 mo after a test (Biddulph and Biddulph 1953).

1954

BRAVO, the first test of Operation CASTLE, was detonated at 6:45 AM on 1 March (local Pacific date, time) at Bikini Atoll. The explosive yield of BRAVO was "three times the most probable predicted value and twice the predicted upper limit. . ." (DNA 1954a).

The winds above 17,000 feet were blowing ENE at the time of detonation (DNA 1979); consequently heavy radioactive fallout was received at Rongelap, Rongerik, and Utrik Atolls, exposing inhabitants there as well as the fishing vessel, the *Lucky Dragon*, which was NE of Bikini. Much lower levels of radioactivity reached various locations in the Marshall Islands including Kwajalein Atoll (Harley et al. 1960) and Majuro Atoll (Breslin and Cassidy 1955^{||}).

Twenty-eight American military personnel were stationed as weather observers on Rongerik Atoll. The onset of visible fallout at Rongerik was approximately 1400–1430 h (Sharp and Chapman 1957). A stationary measurement instrument with strip-chart output that had been placed at the Rongerik Atoll weather station (Eniwetak Island) by HASL (Eisenbud 1990) went off scale at 100 mr h^{-1} at $H + 6 \text{ h}, 48 \text{ min}$ (Sharp and Chapman 1957). Following the radio transmission from Rongerik to the JTF flagship *Estes*, there was an unexplained delay in confirming the reported fallout (Eisenbud 1990; Eisenbud 1997).

The weather observers were evacuated from Rongerik in two different groups: the first eight men were removed about 22.5 h following the onset of fallout (1245, 2 March), the remaining twenty men at about 28 h (1800, 2 March).

Sixteen Marshallese were evacuated by plane from Rongelap at 1000, 3 March ($H + 51 \text{ h}$). Forty-eight Marshallese were evacuated from Rongelap on the USS *Philip* at the same time (total of 64 persons). Eighteen Rongelapese temporarily staying on Sifo Island, Ailinginae, were evacuated on the USS *Philip* at $H + 54 \text{ h}$. Survey measurements on Rongelap Island made by the evacuation team reported readings of $7.2 \times 10^{-8} \text{ C}$

^{||} Both unclassified and classified versions of this report seemed to have existed simultaneously. The unclassified version was available since 1955; the SECRET version was declassified in May 1994.

^{||} The Lulejian report was declassified in 1996.

$\text{kg}^{-1}\text{s}^{-1}$ (1.0 r h^{-1}) to $1.7 \times 10^{-7} \text{ C kg}^{-1}\text{s}^{-1}$ (2.3 r hr^{-1}) in the main village (Sharp and Chapman 1957).[#]

The Rongelap people were taken to Kwajalein for decontamination, examinations, and health care provided by a medical team formed from personnel from the Naval Medical Research Institute (NMRI) and the Naval Radiological Defense Laboratory (NRDL). The team was headed by Dr. Eugene Cronkite. Within the first 24 to 38 h after exposure, about two-thirds of the Rongelap people experienced anorexia and nausea including diarrhea. Many experienced itching and burning of the skin. About 2 wk after exposure, cutaneous lesions and loss of hair was experienced by many. Following a short stay on Kwajalein, the Rongelap people were relocated to Ejit Island (Majuro Atoll).

On 4 March, 159 people were evacuated from Utrik to Kwajalein on the USS *Renshaw*. The Utrik population was not examined by the Brookhaven medical team until March 1957 (Lessard et al. 1980).

Also exposed were three persons *in-utero* on Rongelap, one on Ailinginae, and eight on Utrik.^{**}

Twenty-three Japanese fishermen on board the fishing boat *Fukuru Maru No. 5* (*Lucky Dragon*) were about 90 miles NE of Bikini at the time of the BRAVO detonation. They reported seeing a reddish-white flash and hearing an explosion 7 or 8 min later. Dust began coating the boat about 3 h following the explosion. It was reported that the dust coating was about 0.5 g m^{-2} with an areal activity concentration of 26 GBq m^{-2} (JSPS 1956).

Within a few days, the fisherman were nauseous, and in 7 or 8 d evidence of burns appeared on exposed areas of skin. The fishermen voyaged for approximately 2 wk on the contaminated boat until 14 March when they arrived at Yaizu Harbor, Shizuoka Prefecture, Japan (BICRUK 1954).

On 10 March, the AEC first announced the exposure of the Marshallese (see Associated Press 1954) with the misleading statements that an evacuation was carried out according to plan as a precautionary measure. The *New York Times* also reported that the AEC announced that although some individuals were unexpectedly exposed to radiation, there were no burns and that after the tests were completed, the Marshallese natives would be returned to their homes.

After the return of the *Fukuru Maru* to Japan, a public panic occurred there over the notion of radioactively contaminated tuna (*New York Times* 1954b; Eisenbud 1990; Parrot 1954), which resulted in significant economic damage to the commercial tuna market.

In May, the 154 people evacuated from Utrik in March were returned to their atoll.

On 1 April, the *New York Times* (1954) reported on the press conference presented by AEC Chairman, Lewis Strauss, in which he misled the American public by stating that the skin lesions on the fisherman of the *Lucky Dragon*

"are believed to be due the chemical activity of the converted coral material, rather than to radioactivity. . .".

Joint Task Force Seven (JTF7) reported by memorandum the exposure-rate readings made by radSAFE surveys in the first 5 d following the BRAVO detonation (House 1954). JTF7 also reported on external radiation exposures to military personnel during Operation CASTLE (Servis 1954). The highest reported exposures^{††} were 40 R by weather station personnel on Rongerik and 17 R by one weather reconnaissance pilot. The bulk of Task Force exposures between $1.6 \times 10^3 \text{ C kg}^{-1}$ (6R) and $3.1 \times 10^{-3} \text{ C kg}^{-1}$ (12 R) were reported for Navy ship decontamination and Air Force cloud sampling teams. Reported were 8,101 individuals exposed from $0 - 5.2 \times 10^{-4} \text{ C kg}^{-1}$ (0 - 2 R), 1,440 exposed to $5.2 \times 10^{-4} - 1.0 \times 10^{-3} \text{ C kg}^{-1}$ (2 - 4 R), 549 exposed $1.0 \times 10^{-3} - 1.6 \times 10^{-3} \text{ C kg}^{-1}$ (4 - 6 R), 161 exposed $1.6 \times 10^{-3} - 3.1 \times 10^{-3} \text{ C kg}^{-1}$ (6 - 12 R), and 37 exposed to over $3.1 \times 10^{-3} \text{ C kg}^{-1}$ (12 R).

The CASTLE series continued with four more tests at Bikini Atoll during the 9-wk period following BRAVO and with a single test at Enewetak 1 wk after the Bikini series.

In the spring, JTF7 issued a two-volume radiological safety report of Operation CASTLE. It appears that the original report was classified (an extract for public distribution was later issued by Defense Nuclear Agency in 1985).

During the summer, relationships with Japan improved and a joint U.S./Japan radiobiological conference was held in Tokyo. Research findings from the vessel *Shinkotsu Maru* showed that the radioactivity from Bikini lagoon flowed into the Equatorial and Kurishio Currents which would eventually reach Japan and Asia. HASL prepared a research team headed by John Harley to track the radioactive plume under Operation TROLL; the 3-mo mission began in San Francisco in February 1955. Although the Operation confirmed that concentrations of radioactivity in seafood were below health concerns, it did provide new data on mixing rates in Pacific waters (Eisenbud 1990).

Extensive radiological monitoring throughout the 1954 Castle series was conducted by HASL using continuous reading gamma radiation monitors placed at eleven locations in the Marshall, Caroline, and Mariana Islands and by aerial surveys (Breslin and Cassidy 1955). The instrument located at the main population center, Majuro, documented that fallout from BRAVO resulted in an increase from $4.7 \times 10^{-15} \text{ C kg}^{-1}\text{s}^{-1}$ ($0.065 \mu\text{R h}^{-1}$) to $7.9 \times 10^{-14} \text{ C kg}^{-1}\text{s}^{-1}$ ($1.1 \mu\text{R h}^{-1}$) for about 14 d following the test. Possibly the first successful aerial radiation surveys were conducted over the Marshall Islands as part of the HASL program. Twelve lengthy flights were conducted, some missions surveying as many as sixteen atolls. During this series of aerial monitoring missions, measurement data were collected on all 28 atolls of the Marshall Islands, in addition to

[#] The abbreviation of "r" in Sharp and Chapman (1957) refers to roentgen, now usually abbreviated as "R."

^{**} Confirmed in 1982 (Adams et al. 1982).

^{††} This early report did not have information on internal exposures to the weather observers stationed at Rongerik. See 1986 entry for additional information.

many more distant locations such as the Hawaiian Islands, Midway, Guam, and Palau.

A number of field missions to Rongelap with various sampling objectives were held in 1954: (1) March 26, the Applied Fisheries Laboratory (AFL) visited Rongelap to make radiation readings and capture animals for study; (2) April 13 by U.S. Naval Radiological Defense Laboratory (NRDL) and Naval Medical Research Institute (NMRI); (3) July 16 by the AFL; and (4) December 18 by AFL.

1955

Additional U.S. agency sampling missions to Rongelap were conducted in 1955: (1) January 25 to 30 by NRDL; (2) October 21 to 23 by AFL; and (3) November 7 by AFL.

In January, the AEC Health and Safety Laboratory (HASL) reported on radioactive debris from Operation CASTLE in the Pacific (Breslin and Cassidy 1955) and in worldwide fallout (Lynch 1955). The latter report estimated that the world wide fallout of beta-activity, excluding the test site, was 5.6×10^{16} Bq (1.5 MCi) per month in March, April, and May of 1954, decreasing to 2.8×10^{16} Bq (0.75 MCi) in June and July and 4.4×10^{16} Bq (1.2 MCi) in August.

In February, AEC Chairman Lewis Strauss released an article to the public, "The Truth About Radioactive Fall-Out" (Strauss 1955). In this article he confirmed the then classified predictions of Lulejian (1953) in his reference to the March 1 test at Bikini^{††}: "Thus, about 7,000 square miles of territory downwind from the point of burst was so contaminated that survival might have depended upon prompt evacuation of the area or upon taking shelter and other protective measures." The notion of an "unexpected shift in the winds" as the main cause of the exposure of the Marshallese can be traced to this article despite the evidence that the wind was blowing ENE, dangerously close to the direction of the inhabited atolls, at the time of the detonation.

In March, AFL issued a report (Donaldson et al. 1955) on radioactivity in fish collected at Ponape in late 1954 (then the Trust Territory, now Federated States of Micronesia). Although the analysis as described was limited to gross count-rates, attention was brought to the fact that islanders prefer to consume the liver of fish, thereby resulting in a possible tenfold increase in the radioactivity consumed as compared to consuming equal amounts of fish flesh.

In April, the NMRI and NRDL issued an addendum report on Project 4.1A of Operation Castle: "Medical Examination of Rongelap People Six Months After Exposure to Fallout" (Bond et al. 1955).

In early May, the Navy Foreign Claims Commission settled claims for the damages to Marshallese related to the BRAVO test. A total of \$5,162.53 was paid to Rongelap residents and \$1,719.27 was paid to Utrik inhabitants (Deines et al. 1991).

^{††} Strauss was referring to the BRAVO test but the publication did not give its code name.

A single Pacific Ocean test was detonated as part of Operation WIGWAM in mid-May. The test was located about 640 km SW of San Diego; the 30 kT device was suspended by a cable from a barge at a depth of 600 m.

Possibly the first open literature publication describing the acute health effects among the Rongelapese was published in the *Journal of the American Medical Association* in 1955 (Cronkite et al. 1955).

The Applied Fisheries Laboratory reported on their various surveys of Rongelap during 1954 and 1955 (Donaldson 1955). From March 1954 to January 1955, the radioactivity in coconut meat and milk declined to about 4% of its initial value though measurements were limited to the gross beta-decay rate.

1956

Operation REDWING was conducted May through July at both Bikini and Eniwetak Atolls and included 17 tests, several of which were hydrogen bombs.

Additional sampling missions to Rongelap were conducted: (1) February 7 to 14 by NRDL and (2) July 23 to 24 by AFL. The survey at the end of July found external dose-rates on Rongelap Island to be about 1.4×10^{-11} C kg⁻¹ s⁻¹ (0.2 mR h⁻¹) – 3.6×10^{-11} C kg⁻¹ s⁻¹ (0.5 mR h⁻¹) with an average of 2.9×10^{-11} C kg⁻¹ s⁻¹ (0.4 mR h⁻¹) (AEC 1957). The exposure rate was noted to be higher than anticipated by considering the theoretical decay rate of BRAVO fallout and was attributed to additional radioactive fallout received on Rongelap from Operation REDWING.

In November, The U.S. Government completed an agreement with the Eniwetak chiefs through the TT High Commissioner, allowing the Eniwetak people full use of Ujelang Atoll until they could return to Eniwetak; the sum of \$175,000 was provided for assistance.

In the same month, a similar agreement was settled with Bikini and the sum of \$325,000 was provided.

1957

In March an addendum report of Project 4.1 of Operation Castle was issued on "Exposure of Marshall Islanders and American Military Personnel to Fallout" (Sharp and Chapman 1957). The report detailed the homes, water catchments, etc., of the Rongelap community as well as the movements of the service personnel in the hours after fallout and before evacuation. The report also included film-badge readings from the service personnel.

In February, the AEC approved the return of the Rongelapese to their atoll based on the projection of an exposure of 1.3×10^{-4} C kg⁻¹ (0.5 R) in the first year, declining thereafter. In mid-June, measurements showed the external exposure-rate to be about 2.1×10^{-12} C kg⁻¹ s⁻¹ (0.26 R y⁻¹). On 29 June, about 250 people were returned to Rongelap Island, including those originally evacuated and some additional people added by marriage and birth.

Brookhaven National Laboratory (BNL) developed a whole-body gamma scintillation spectrometer for the purpose of measuring the internal radioactivity of

Rongelap people. Members of the Rongelap community were transported by air to the U.S. for whole-body counting. Dr. Robert Conard of BNL took over directing the medical surveillance program of the exposed Marshallese.

In August, the AEC issued a report entitled "Radioactive Contamination of Certain Areas in the Pacific Ocean From Nuclear Tests" (AEC 1957). Despite the elusive title, the document summarized data from the radiological surveys of Rongelap and the medical examinations of the evacuated populations.

1958

The last series of Marshall Islands tests was conducted as Operation HARDTACK I. Both Bikini and Enewetak Atolls were used for the 35 detonations.

A "portable" 21-ton steel whole body counting facility was developed by BNL to take to Rongelap aboard a landing craft for whole-body counting of the Rongelap community members.

The United States, Great Britain, and USSR suspended nuclear weapons testing as part of a nuclear testing moratorium on 31 October.

POST-TESTING ERA

1960

The University of Washington Laboratory of Radiation Biology (LRB, previously AFL) issued a report (Palumbo 1960) on the recovery of land plants at Enewetak following the testing. LRB also issued a report (Chakravarti and Held 1960) on ^{137}Cs in the coconut crab (*Birgus Latro*) collected from Rongelap Atoll during 1958. The coconut crab, recognized to be a delicacy to Marshallese, was found to contain high levels of ^{137}Cs due to its diet of fresh coconut.

1962

A book was published describing the radiobiological studies in the Pacific during the years 1946–1961 (Hines 1962).

The Federal Radiation Council issued the first report on the pathological effects of thyroid irradiation, summarizing the experience of the Rongelapese to date (FRC 1962).

1963

Nine years after exposure to BRAVO fallout, the first thyroid nodule in the heavily exposed Rongelapese was detected (diagnosed in a 12-y-old girl, i.e., 3 y of age at exposure).

The first paper was published on the chemical and radiochemical composition of the Rongelapese diet (Chakravarti and Held 1963). High dietary intake levels of ^{137}Cs and ^{90}Sr were noted where local fruit was consumed, and ^{60}Cs and ^{65}Zn were associated with diets of local fish.

1964

The University of Washington's Laboratory of Radiation Biology resurveyed Bikini. Compensation for exposed Rongelapese as a result of BRAVO fallout was

appropriated by P.L. 88-485 in the amount of \$950,000. The compensation was considered as a full settlement of all claims against the U.S. (U.S. 1964; Deines et al. 1991).

1965

Held (1965) reported on gamma dose rates on Rongelap during the years 1954 to 1963 and concluded that the exposure rate had decreased faster in the environment than predicted by the theoretical decay of ^{235}U . The reason given was due to the downward movement of ^{137}Cs in the soil. Their data also showed that the dose rate on Rongelap Island at $D + 1$ (time of detonation plus one day) was $9.8 \times 10^{-6} \text{ Gy s}^{-1}$ (3.5 r h^{-1}) and $9.8 \times 10^{-5} \text{ Gy s}^{-1}$ (35 r h^{-1}) on Lomuila Island in the northern part of the atoll.^{§§}

Held et al. (1965) also reported on redistribution of radionuclides in soils following fallout contamination. Some basic tenets of radioecology resulted from those studies, including the observations that soil algae, found as a surface crust in undisturbed areas, had the highest levels of radioactivity and that vegetation litter redeposits ^{137}Cs and ^{90}Sr back to the surface layer of soil.

1966

The National Academy of Sciences issued an updated version (FRC 1966) of its 1962 report on pathological effects of thyroid irradiation, further summarizing the experience to date of the exposed Rongelapese.^{|||} By this date, 79% of children less than 10 y of age at time of exposure had developed thyroid abnormalities as compared to no thyroid pathology in non- or lesser-exposed populations.

In 1966, an open literature publication summarized the induction of thyroid nodular disease among the exposed Rongelapese (Conard et al. 1966).

Secretary of the Interior, Stewart Udall, advised AEC Chairman Seaborg that the Department of the Interior was anxious to determine whether the Bikini people could be returned to the homeland and requested the AEC to make that determination as soon as possible.

1967

Following a request in 1966 from the High Commissioner of the Trust Territories of the Pacific to the AEC to rehabilitate Bikini, the atoll was resurveyed in April and May by personnel from HASL, the Division of Biology and Medicine (DBM), NRDL, the Trust Territory (TT), and University of Washington (UW). A report by HASL was issued on the external radiation levels determined by the survey (Beck et al. 1967).

^{§§} The abbreviation of "r" refers to roentgen, now usually abbreviated as "R."

^{|||} The reader should take note that two of the four conclusions of the 1966 report are still topics of research and, although not yet fully resolved, some of these questions may be answered by studies of the effects of the Chernobyl accident: (1) The shape of the response curve below 1 Gy (100 rad) is unknown. (2) X rays are probably as effective if not more so than ^{131}I in producing thyroid lesions for equal, average absorbed doses delivered to the gland at similar rates.

In October, 300 Enewetak people living on Ujelang were moved to Majuro for better food and improved living conditions.

1968

In April, the AEC DBM appointed an *Ad Hoc* committee of eight experts to consider the question of return of the Bikini population (McCraw n.d.).

In August, President Johnson publicly announced the decision to resettle the Bikini people on their home atoll (AEC 1968).

1969

In February, a clean-up phase as part of the rehabilitation of Bikini was begun by the AEC and Department of Defense (AEC 1971) and was completed by October. The *Ad Hoc* committee reviewing the 1967 survey concluded that the Bikini-Eneu complex of islands could be used for continuous occupancy and agricultural development to support the returning population. The committee stated that, on the basis of information provided, the exposures to radiation resulting from the repatriation of Bikini people would not offer a significant threat to their health and safety (McCraw n.d.; AEC 1968). The committee further recommended that test-related debris should be removed to eliminate physical hazards. The concentrations of ^{90}Sr in the food chain were believed at that time to be the primary hazard with respect to internal dose. The committee's recommendations were made to the Chairman of the AEC who informed the Secretary of the Interior, the Administrator for the Trust Territory of the Pacific.

About 40 people began living on Eneu Island, Bikini Atoll. A general cleanup of debris and buildings was begun. An agricultural reclamation program was initiated with the planting of coconut trees on Eneu and Bikini Islands. Pandanus, papaya and banana were planted on Bikini Island (Robison et al. 1977). Construction of 43 houses was begun (continuing until 1974).

1971

The AEC issued a summary report of the 1969 and 1970 surveys of Bikini Atoll (AEC 1971).

1972

In January during the Congress of Micronesia, a Marshall Islands representative accused the U.S. of intentionally exposing the inhabitants of Rongelap and Utrik to develop medical capabilities for treating radiation exposure during wartime. In response to the accusations, the Rongelapese boycotted the BNL medical survey charging them with using the Rongelap people as guinea pigs.

The 40 people living on Eneu Island (Bikini Atoll) and an additional 20 women and children moved to Bikini Island. Additional monitoring was conducted by AEC Division of Operational Safety with support of the AEC Nevada Operations Office, UW and the Western Environmental Research Laboratory of the Environmental Protection Agency.

Plans continued for a cleanup of Enewetak Atoll. An interagency meeting delegated responsibilities for fund-

ing the pre-cleanup survey to AEC, the radiological and nonradiological cleanup to DOD and the rehabilitation costs to DOI. In October, the pre-cleanup radiological survey of Enewetak began.

The only documented death from radiation-induced leukemia among the exposed Rongelapese occurred in a 19-y-old male, exposed at age 1 y (Conard 1975). He died at the National Institutes of Health, where he was being treated.

1973

Field operations of a survey of Enewetak (pre-cleanup survey) were completed in February.

Testimony provided during House Appropriations Committee hearings disclosed that urine bioassays of people intermittently resident on Bikini showed ^{137}Cs higher than in 1970 by about $10\times$ and ^{90}Sr higher by about $4\times$. The increase in body burdens was attributed to the consumption of fruits grown on Bikini Island.

1974

Compensation was paid by the AEC to the TT in the amount of \$18,212, to be dispersed in equal payments of \$116 to the exposed Rongelapese or their heirs.

The AEC task group recommended cleanup levels for plutonium contaminated soil at Enewetak Atoll: 1.48 Bq g^{-1} (40 pCi g^{-1} original units)—no action required; 1.48 to 14.8 Bq g^{-1} (40 to 400 pCi g^{-1})—corrective action determined on a case-by case basis (related to projected land use); and greater than 14.8 Bq g^{-1} (400 pCi g^{-1})—corrective action required.

President Ford created the Energy Research and Development Administration (ERDA).

1975

A survey of Bikini and Eneu Islands was conducted by Lawrence Livermore National Laboratory (LLNL) under contract with ERDA to determine low-exposure sites for additional housing.

In June, P.L. 94-34 authorized an *ex gratia* payment of \$3 million to the people of Bikini in recognition of the hardship they endured (U.S. 1968).

In September, the DOD discussed the postponement of the resettlement of Bikini, implying that a radiological survey of Bikini, similar to the pre-cleanup survey of Enewetak, might be necessary. The Bikinians brought a lawsuit in U.S. District Court in Hawaii to force the U.S. to stop the resettlement until a comprehensive radiological survey of the atoll was conducted.

1976

Brookhaven National Laboratory (BNL) conducted an external radiation survey program of five northern atolls and, in April, surveyed some of Bikini Atoll.

1977

In March, 56 Enewetak community members returned to Japtan Island in Enewetak Atoll.

In August, President Carter created the Department of Energy (DOE) by Public Law 95-91.

P.L. 95-134 mandated a continuous medical care program for the Marshallese exposed to BRAVO fallout.

A report was issued by LLNL to assess dose to returning Bikini residents (Robison et al. 1977).

1978

In April, urine was sampled from the Bikini residents by BNL; those data and ^{137}Cs body burdens determined by whole-body counting were reported to the DOE in July. Body burdens of several individuals exceeded the maximum permissible body burden (MPBB) of 1.1×10^5 Bq (3.0 μCi), and values for a dozen individuals ranged between 2.2×10^4 Bq (0.6 μCi) and 2.2×10^5 (5.9 μCi) (Greenhouse 1978). In September, as a result of the increases in body burdens, the Bikini residents were again relocated to Kili Island.

The Northern Marshall Islands Radiological Survey began in September under a contract issued by the DOE to EG&G for aerial monitoring of eleven atolls. A helicopter mounted NaI detector array was used for gamma spectrometry measurements. LLNL also acquired plant and soil samples as part of the monitoring program.

A \$75M settlement with Bikini for damages resolved claims against the U.S. for taking and using Bikini as a testing grounds (Weisgall 1994).

1979

DNA (1979) issued a "Compilation of Local Fallout Data" for oceanic tests. This volume gave the H hour, H + 3 hour, and H + 6 hour hodographs for the BRAVO test clearly showing the winds above 17,500 feet to have been blowing ENE.

In March and April, the DOE through LLNL conducted a survey of Enjebi Island (Enewetak). In September, a concrete dome was completed over a radioactive waste repository made from the CACTUS (shot) crater on Runit Island (Enewetak). Over 100,000 m^3 of soil contaminated with transuranic radionuclides, principally isotopes of plutonium and americium, were mixed with cement and imbedded in the crater.

Twelve of the twenty-eight military personnel exposed on Rongerik to BRAVO fallout were medically examined in possibly the only medical follow-up of this exposed group (Bailey 1995).

1980

In March, the cleanup of Enewetak Atoll was completed at an estimated cost of \$218 million (Deines et al. 1991). Over 4,000 U.S. servicemen assisted in the cleanup effort and six lives were lost in accidents. In May, the Enewetak people returned to their atoll.

In the fall, DOE issued the "Meaning of Radiation at Bikini Atoll" (DOE 1982a). The report stated that the Bikini people would be within U.S. radiation standards if they returned to Eneu Island, that they ate no more than 50% locally grown food and spent no more than 10% of their time on Bikini Island. (In the 2 y following, 14 petitions on behalf of approximately 5,000 Marshallese were filed in U.S. Court of Claims. The alleged damages in these suits totaled \$5.75 billion.)

BNL published a reconstruction of chronic dose equivalent to Rongelap and Utrik residents for the years 1954 through 1980 (Lessard et al. 1980). Doses were relatively high for Utrik residents because the Rongelapese had been relocated from their atoll following the BRAVO test until late June of 1957. Estimated doses to adults were 0.17 Sv (17 rem) and 0.039 Sv (3.9 rem) to whole-body (Rongelap and Utrik, respectively), 0.16 Sv (16 rem) and 0.045 Sv (4.5 rem) to thyroid (Rongelap and Utrik, respectively), 0.23 Sv (23 rem) and 0.049 Sv (4.9 rem) to red bone marrow (Rongelap and Utrik, respectively).

1981

Following the Enewetak cleanup, 100 Enewetak people returned to Ujelang from Enewetak because of insufficient locally grown food.

Calculations were performed for DNA (Gminder 1981) to estimate the radiation dose to a representative individual on Kwajalein Atoll from 1 May to 18 September 1948 during the rainout of radioactive fallout from Shot YOKE of Operation SANDSTONE. The external exposure (maximum value, no building shielding) was estimated to have been 7.7 mSv (770 mrem).

Findings of the EG&G aerial survey were released in a report (Tipton and Meibum 1981) that gave exposure-rate values and estimated soil concentrations of selected fission products on 11 atolls and two separate reef islands.

1982

The U.S. Congress created a \$20 million Resettlement Trust Fund to be used for upgrading and improving living conditions for the Bikini people on Kili Island.

Congress created the Bikini Atoll Rehabilitation Committee (BARC) to investigate the feasibility and costs of rehabilitating Bikini. The committee was chaired by Dr. Henry Kohn.

LLNL updated its dose assessment for Bikini (Robison et al. 1982b) and published the results of the ground sampling from the 1978 survey of the northern Marshall Islands (Robison et al. 1982a).

The Department of Energy issued a bilingual report (English/Marshallese) in 1982 (DOE 1982b) explaining the meaning of radiation and giving information on the radiological conditions on the northern atolls as obtained by the 1978 aerial survey. For the first time in this report, Marshallese were given information that showed that islands of northern Rongelap Atoll were as contaminated as Bikini Island.

The 28-y follow-up medical report from Brookhaven National Laboratory (Adams et al. 1982) confirmed two additional individuals *in-utero* on Utrik at the time of the BRAVO fallout. The report also listed the previous 64 BNL publications concerning follow-up of exposed Marshallese. Updated dose assessments for the Marshallese known to have been exposed to BRAVO fallout were also provided in an appendix.

1983

In May, the Bikini people filed a class action suit against the executive branch of the U.S. Government seeking compensation for damages to Bikini.

The DOE Marshall Islands dose assessment programs were transferred from Emergency Preparedness to Defense Programs within the DOE.

The Compact of Free Association was approved by the electorate of the Marshall Islands.

The Rongelap community decided that, due to the startling evidence of contamination of their atoll brought to light in DOE (1982b), they must abandon their atoll (King 1986) and began to solicit internationally for evacuation assistance.

1984

In February, LLNL published results of calculations (Hicks 1984) for a limited number of Marshall Islands tests giving the relationship between external gamma exposure rates for local fallout and the related radionuclide composition.

In November, BARC submitted its first report to Congress stating that Bikini Island may be resettled if no locally grown food or ground water is consumed for 80 y. The Bikini council rejected that option.

The Bikinians, disappointed with the Compact of Free Association, an agreement under negotiation between the U.S. and the Marshall Islands, brought a suit in U.S. Federal Court in Honolulu to attempt to force the U.S. to conduct a cleanup and to hastily resettle the Bikini people to their atoll.

1985

The lawsuit of the Bikinians was settled on March 15 with the U.S. agreeing to conduct a cleanup upon completion of the findings of BARC.

In May, 327 Rongelap people went into self-imposed exile as a result of their fear of the radioactive contamination of Rongelap brought to light by the 1982b DOE report of the northern Marshall Islands radiological survey.^{¶¶} After an international plea for evacuation assistance that lasted several years, the Rongelapese left Rongelap Atoll for Mejjatto Island (Kwajalein Atoll) with the assistance of the Greenpeace organization. Taking four trips of the *Rainbow Warrior* (King 1986) to move the community and their belongings, the Rongelap people settled on Mejjatto.^{##}

Lessard et al. (1985) reported results of calculations to estimate acute thyroid exposure to residents of Rongelap, Ailinginae, and Utrik Atolls from the BRAVO test. They concluded that ingestion was the main route of internal exposure. Whole body exposure was estimated at Rongelap to be about 1.75 Sv (175 rem). Thyroid doses (internal dose + external exposure) at Rongelap from

BRAVO were estimated for the age categories of adult, 9 y, 1 y, newborn and *in utero*: 12 Sv (1200 rem), 22 Sv (2200 rem), 52 Sv (5200 rem), 44 Sv (4400 rem) and 8.7 Sv (870 rem), respectively. Maximum estimates were about 4× greater. Dose estimates at Ailinginae and Utrik were about 30% and 15%, respectively, of the Rongelap estimates.

The Compact of Free Association (COFA) was passed by the U.S. Congress (as part of P.L. 99-239) and enacted a \$150 million compensation program to the Marshall Islands. Under Section 177 of the COFA, the people of Bikini, Enewetak, Rongelap, and Utrik were awarded \$75 million, \$48.75 million, \$37.5 million, and \$22.5 million, respectively, to be paid in quarterly installments over a 15-y period. The COFA also made available \$3 million to conduct medical surveillance and radiological monitoring.

In September, the Defense Nuclear Agency (DNA) issued an extracted version (DNA 1954a, b) of the JTF7 Final Report on Radiological Safety written in 1954.

1986

In January, President Reagan signed P.L. 99-239, which enacted the Compact of Free Association (COFA); it became effective in October.

A report (Klemm et al. 1986) was issued by Science Applications International Corporation for the DNA on the analysis of radiation exposure to service personnel on Rongerik Atoll at the time of shot BRAVO. External doses for the first and second evacuation group were estimated at 0.33 Sv (33 rem) and 0.38 Sv (38 rem) to 0.43 Sv (43 rem), respectively. Internal doses varied by organ: representative estimates were 2.3 Sv (230 rem) to the thyroid, 1.15 Sv (115 rem) to lower large intestinal wall, 0.85 Sv (85 rem) to upper large intestinal wall, and 0.4 Sv (40 rem) to 0.5 Sv (50 rem) to other organs (Klemm et al. 1986; Goetz et al. 1987).

1987

In August, the Republic of the Marshall Islands (RMI) contracted Dr. Henry Kohn, previous chairman of BARC, to chair a review of the 1982 DOE report on the findings of the 1978 radiological survey of the northern Marshall Islands. The purpose of the review was "to determine whether or not DOE's 1982 Report proved that the Rongelap Island is safe for habitation" (Kohn 1989a, b). The Rongelap Reassessment Project was formed as a result, and a panel of consultants was selected to provide expertise on various scientific and technical issues.

Also in August, Hamilton et al. (1987) published results of a thyroid screening program conducted during the previous 4 y in the RMI. This paper concluded that there is an excess of thyroid nodular disease in the southern Marshall Islands as well as the northern atolls, with the prevalence decreasing with increasing distance from Bikini. The paper hypothesized that radioactive contamination from the nuclear tests in the Marshall Islands was more widespread than previously known.

^{¶¶} The creation of fear among Rongelap community members as a result of the 1982 report is difficult to document. The Mayor and Senator of Rongelap wrote in a letter to H. I. Kohn in 1988: "The 1982 DOE report and revelations contained in it terrified our people. . . . The disclosure in 1982 made it evident that DOE was not truthful with the Rongelap people from 1957 to 1982 regarding the level of atoll contamination. . . . We have become Pacific nomads, not out of choice, but of fear. . . ." (Mwekto and Anjain 1988).

^{##} The Rongelap people are still resident on Mejjatto today though part of the community has split off to Majuro and Ebeye (the two main population centers of the Marshall Islands).

In July, LLNL published a dose assessment for Enjebi Island (Enewetak) (Robison et al. 1987). The average whole-body effective dose-equivalent was estimated as 1.69 mSv y^{-1} (169 mrem y^{-1}) in 1990.

In November, the U.S. Claims Courts dismissed several billion dollars of suits filed in 1980, contending that the COFA withdrew the consent of the U.S. to be sued for claims arising from the atomic weapons testing program in the Marshall Islands.

The Nuclear Claims Tribunal Act was enacted in the RMI creating a judicial body for administering the compensation funds made available by the COFA (RMI 1987).

The first compensation payments were made in 1987 to the people of Bikini, Enewetak, Rongelap and Utrik as outlined in Section 177 of the COFA.

1988

In June, the Mayor and Senator of Rongelap wrote to the Chairman of the Rongelap Reassessment Project stating that it was to their understanding that their study was now controlled by the Department of Energy, and that information concerning contamination and health of Rongelapese was being withheld.

In July, the Rongelap Reassessment Project (Kohn 1988) issued a report stating that Rongelap Island is safe for habitation provided that the diet is equivalent to that formerly used. Among other conclusions stated in the abstract were the following: "the dose to infants and small children is another potential cause of concern. . ." and "In the course of planning for Atoll resettlement, the fact that Rongelap Island appears safe for resettlement now should not be lost site of." Kohn addressed the concerns of the Mayor and Senator as a number of misunderstandings.

In December, the U.S. Courts of Appeals sustained the Claims Courts decision to dismiss Marshallese lawsuits.

The final BARC report was issued, suggesting potassium treatment of the soil to be an effective mitigation technique to prevent the uptake of ^{137}Cs into food crops and estimating costs of \$66 to \$100 million for rehabilitation of Bikini and Eneu Islands.

The U.S. Congress appropriated \$90 million to be paid during 1988 through 1992 to the Bikini Resettlement Trust Fund so that a radiological cleanup of Bikini and Eneu Islands could be conducted.

1989

In February, the Nuclear Claims Tribunal and the RMI Government solicited internationally for independent scientific advisors and a resident scientist to direct a nationwide monitoring program which would use funds from Section 177 of the COFA.

The Rongelap Reassessment Project issued its 2nd report in March (Kohn 1989a). In April, a \$6.6 M "Phase 2" study of Rongelap was proposed from a U.S. engineering firm (P&D 1989) including testing the plutonium mining cleanup technology developed by the DNA for Johnston Atoll (Bramlitt 1988). The project was not funded by Congress.

Also in April, the Department of Energy issued a summary of information in the Marshallese language concerning Enjebi island (Enewetak Atoll) (DOE 1989). The report recommended that future Enjebi inhabitants maintain a source of imported foods to prevent individual exposures from exceeding 1.7 mSv y^{-1} (170 mrem y^{-1}).

LLNL published an analysis of doses received by adults as compared to children in the northern Marshall Islands (Robison and Phillips 1989). The report concluded that adult estimates could be treated as conservative estimates for children.

A detailed survey of soils found in the Marshall Islands was issued (USDA 1989) by the U.S. Department of Agriculture to assist the Marshall Islands in agronomy, construction and conservation.

The Marshall Islands Government recruited a resident scientist in October (S. L. Simon) to direct the first nationwide radiological monitoring program of the Marshall Islands. As part of that initiative, a five-member Scientific Advisory Panel was appointed without any American participation.

In November, Senator Jeton Anjain of Rongelap testified to the House Appropriations Committee that the independent study of Rongelap promised in P.L. 99-239 should be initiated as soon as possible. In December, Senator Anjain testified before the DOE Secretarial Panel for the Evaluation of Epidemiological Research Activities (SPEERA) that the DOE Defense Programs could not be objective in the management of the Marshall Islands dose assessment programs.

1990

A revised edition of the report of the Rongelap Reassessment Project was issued in March (Kohn 1989b) following Congressional hearings in November 1989 and May 1990.

In March, the Secretary of Energy directed the consolidation of medical surveillance, epidemiology, and other health matters into the new office of Environmental Safety and Health. Marshall Islands programs were transferred from Weapons to the new division.

The Rongelapese representatives continued to lobby Congress for an independent evaluation of the radiological conditions of Rongelap.

1991

The Marshall Islands Nationwide Radiological Study, a study supported by the Marshall Islands Government, finished the construction of a dedicated radiological laboratory in Majuro (capital city of the Marshall Islands) for the purpose of supporting their monitoring program.

The first individual claims were paid to Marshallese by the Nuclear Claims Tribunal under the process enacted by the COFA.

A report was issued by the U.S. National Parks Service (Delgado et al. 1991) describing the unique archeological artifacts in the lagoon of Bikini Atoll: ships sunk by Operation CROSSROADS in 1946.

1992

In February, a four-way Memorandum of Understanding was signed between the DOE, DOI, RMI Government, and Rongelap Local Government. Though the document provided few binding responsibilities, it called for two independent studies (by Rongelap and DOE) to determine (1) if the maximally exposed person while living on Rongelap Island and eating only locally produced food would exceed 1 mSv y^{-1} , and (2) whether soil concentrations of transuranics on Rongelap Island exceeded a $7.4 \times 10^3 \text{ Bq m}^{-2}$ ($0.2 \mu\text{Ci m}^{-2}$) guideline of the EPA (EPA 1990a, b). Compliance with both conditions would imply that resettlement could begin without consideration for mitigative actions (see Simon et al. 1997).

The Rongelap Resettlement Project came into being with the signing of the four-way MOU and the appropriation of \$1.6 million from DOI. The project fulfilled the independent assessment promised under P.L. 99-239. The project was administered by the Rongelap Local Government, and oversight was provided by a six-person panel representing five countries. Scientific investigation was contracted to a Scientific Management Team (K. F. Baverstock, B. Franke, S. L. Simon) appointed by Rongelap leaders.

Gessell and Walker (1992) published findings on soils and plants of the Northern Marshall Islands from studies conducted by the authors from 1958 to 1964.

S. L. Simon requested through the Ministry of Foreign Affairs of the Republic of the Marshall Islands data on the explosive yields on the nuclear tests conducted at Bikini and Enewetak. Prior to that date, explosive yields for 45 of 66 tests were still classified.

1993

Late in 1993, the U.S. Secretary of Energy released the explosive yields of the tests conducted in the Marshall Islands to the RMI Government and the U.S. public as part of an "Openness Initiative" (DOE 1993).

The Marshall Islands Nationwide Radiological Study began the first phase of a thyroid disease screening program intended to re-examine the findings and hypothesis of Hamilton et al. (1987). During 1993, thyroid examinations were provided to 1,367 Marshallese who live on Kwajalein Atoll (Takahashi et al. 1997).

1994

On 24 February, the House of Representatives Subcommittee on Oversight and Investigations of the Committee on Natural Resources held a hearing on "Radiation Exposure From Nuclear Tests in the Pacific" with an emphasis to disclose the circumstances leading to the exposure of Marshallese from the BRAVO test. Written and oral testimony (Congress 1994) was provided by a number of witnesses including M. Eisenbud, S. L. Simon, T. Hamilton, E. Radford and numerous Marshallese delegates. Few conclusions were reached as a result of the hearing though it was a landmark as it was the first public hearing on the BRAVO incident.

In April, the Scientific Management Team of the RRP issued an Executive Summary of its findings (SMT 1994) and on May 5 presented it to the House Appropri-

ations Committee. A slightly revised version was issued in November. The findings of the RRP included that the compliance limit of 1 mSv y^{-1} would likely be exceeded by 25% to 75% of the population, depending on dietary assumptions. The compliance limit for transuranic concentration in soil was found to be only exceeded by about 1% of the samples, thus it was not seen as an impediment to resettlement. Recommendations were made to minimize the contribution of ^{137}Cs to the diet so as to reduce the expected dose and enable a resettlement of Rongelap Island to take place.

In mid-year, the Marshall Islands Government began serious consideration of a proposal talked about for numerous years—commercial storage of high-level nuclear waste. Reporting of their interest appeared in various Pacific press (e.g., Davis 1994), and strong opposition was voiced by Greenpeace and many of the South Pacific nations (North 1994). Bikini was the main site of consideration for the storage although Bikini Local Government were affronted with the passage of a bill by the Marshall Islands Nitijela (Legislature) that the President of the Marshall Islands and other traditional chiefs would receive a third of any income Bikini derived from nuclear storage (North 1994).

In December, the Marshall Islands Nationwide Radiological Study issued its summary report to the Cabinet of the Government of the Republic of the Marshall Islands on the radiological conditions of all the atolls (Simon and Graham 1994). Endorsement of the report by the Scientific Advisory Panel was provided in a letter to the Cabinet and in a formal presentation to the Cabinet. Findings showed that soil ^{137}Cs was elevated above the value expected in the mid-Pacific at atolls further north than 9° (see Simon and Graham 1997); measurements confirmed minimal amounts of fallout contamination as far south as Kwajalein Atoll though only four atolls (Enewetak, Bikini, Rongerik and Ailinginae) had islands where habitation might result in doses in 1995 in excess of 1 mSv y^{-1} .

The National Academy of Sciences, National Research Council (NRC 1994) issued its report evaluating the DOE Marshall Islands programs with emphasis given to an assessment of Rongelap. The environmental measurement programs of DOE through LLNL were found to be credible although some recommendations were given to improve the assessment for a returning population to Rongelap. The estimated doses by NRC were nearly identical to those produced by the Rongelap Resettlement Project (i.e., SMT 1994; SMT 1995; also see Simon et al., 1997).

A publication discussing the intake of natural ^{210}Pb and ^{210}Po from a seafood based diet (Noshkin et al. 1994) showed that the background radiation dose to Marshallese was comparable to that received in continental locations because the intake of seafood compensated for the lower terrestrial exposure on the coral atolls.

The most comprehensive list to date of U.S. atomic tests was issued by the Department of Energy (DOE 1994).

The Marshall Islands Nuclear Claims Tribunal reported that, at the end of the year, \$32,440,750 had been

awarded to 830 individuals in compensation for damages assumed to have been brought about by the nuclear testing program.

1995

The complete report of the RRP with technical appendices of all scientific work undertaken was issued in May (SMT 1995).

The Marshall Islands Nationwide Radiological Study began the second phase of a thyroid disease screening program intended to re-examine the findings and hypothesis of Hamilton (1987). In this phase of work, 5,265 Marshallese were examined who lived mainly on Majuro Atoll.

The Marshall Islands Government continued soliciting for funding for feasibility studies to store high level nuclear waste on one of the atolls, and further opposition was voiced in Pacific news media (e.g., Rashid 1995). In March, the Bikini Local Government Council seriously considered the option of storing high-level nuclear waste on one of the islands of Bikini Atoll as a commercial venture; after a 2-mo emotionally debilitating debate, the Council decided against the idea (Neidenthal 1997).

The most recent report (sixteenth in a series) to disseminate information concerning the 253 Marshallese exposed to BRAVO fallout was published by Brookhaven National Laboratory (Howard et al. 1995).

In October, the Marshall Islands Nitijela (Parliament) passed Bill No. 151 which rejected the findings of the Nationwide Radiological Study which they had financed, stating that the Republic had not accepted the findings as valid or accurate.

In October, the Marshall Islands Nitijela (Parliament) also passed Bill No. 232 which amended the Marshall Islands Nuclear Claims Tribunal Act to extend rights to compensation to any Marshallese who were physically present (including *in utero*) at any time after 30 June 1946, or who is the biological child of a mother who was physically present (including *in utero*) in the Marshall Islands any time after 30 June 1946. The law states: "a casual relationship between a presumed medical condition and the United States Nuclear Testing Program will be presumed, and the presumed medical condition shall be treated equally in all respects, including compensation" (Nitijela 1995).

President Clinton's Advisory Committee on Human Radiation Experiments (ACHRE) heard testimony that Marshallese had been purposefully exposed as "guinea pigs"; the committee also reviewed historical documents of studies conducted soon after the BRAVO exposure. The ACHRE concluded that they found no evidence to indicate that the exposures were motivated by research purposes (ACHRE 1995).

SUMMARY AND CONCLUSION

This chronology illuminates a 50-y saga and several important points. First, there is no doubt that unsuspecting Marshallese were irradiated as a consequence of the nuclear testing program and that several communities

were displaced without their full consent. Likewise, it is indisputable that there has been land and crop damage, land contamination, and some induction of radiogenic disease. The extent of those damages will always be a matter of contention and disagreement.

The significance of the environmental and social consequences following the testing however, has been fully appreciated by the international community of scientists. The many monitoring and ecological studies, medical programs, and compensation programs attest to this. For example, seven agencies of the United States Government played major to minor roles at one time or another in a effort to remediate the damages to the Marshall Islands. These are named in the text. At least six major U.S. laboratories and university organizations have taken part in the evaluation of contamination, the course of the exposures, establishment of doses, health care, and logistic support. Several agencies and universities in Japan took part in the matter of the *Lucky Dragon*. At least as many separate and distinct advisory committees were formed as there were agencies involved in the studies. Even so, each committee reported and disbanded only to be replaced by a similar group with a different composition and a slightly different charge. Recommendations have come and gone with still no complete solution at hand. There have been at least four formal surveys of environmental radioactivity levels and contamination of food and human beings, each taking several years to complete with two long term U.S. sponsored programs still in effect.

Over \$300 million dollars has been awarded directly to groups of Marshallese people to compensate them for social and physical damages. Many more millions have been spent in support of the many surveys, committees, U.S. national laboratory programs, the Marshall Islands own radiological monitoring program, care of the exposed individuals, and attempts to make the islands again basically inhabitable by cleanup and community rebuilding. Yet, with all of this travail, the lives of numerous Marshallese are still affected today by the long since completed atomic weapons testing program. In short, all the displaced Marshallese are not home yet and others who are not displaced continue to fear ill health. Many are still unhappy for one reason or another including the feeling that they have been made into "guinea pigs." It is a tragic dilemma for all concerned. Whether or not the future will see a complete solution is unclear. It is clear, however, the whole episode can serve a larger purpose: The public health must always be given primary consideration in light of what we have learned about widespread radioactive fallout, the consequences of which can extend over many decades.

It is hoped that this written history has served to illuminate the record of science as well as the human story. Neither is separate from the other just as the lives of Marshallese are not really separate anymore from the lives of Americans. The cold war brought the two together in a way that must be recognized and dealt with fairly, regardless of the difficulties.

POSTSCRIPT

Certain developments from 1995 to the present (1997) are worth noting.

Endorsement of the Nationwide Radiological Study (NWRS) as well as interpretations of the scientific findings of that study were given to the RMI Government in December 1994 by the Scientific Advisory Panel they had selected. The Summary Report (Simon and Graham 1994) of the Nationwide Radiological Study to the Cabinet of the RMI included their letter of approval. Some highlights of their letter are as follows.

"In 1989, you appointed us as members of the Scientific Advisory Panel to the Nationwide Radiological Study. . . We have reviewed this report in detail and we endorse it and commend it to you. . . We believe that the current levels of radioactive contamination of the territory of the Marshall Islands pose no risk of adverse health effects to the present generation. . . Four atolls have been identified where exposure rates are elevated to the extent that remedial actions are indicated for some islands."

Additional support for the scientific findings and interpretation of the Nationwide Radiological Study came from two other sources: the Technical Oversight Group of the Rongelap Resettlement Project (including scientists from Germany, UK, New Zealand and Japan) and the report of National Research Council (NRC 1995). The assessment for Rongelap made by the NWRS was very close to that reported by the NRC.

Despite these various expressions of support for the findings of the NWRS, the RMI Nitijela (Parliament) in its 16th session (August 1995) adopted Resolution No. 151 which rejected the findings of the radiological study. Major points of the lengthy resolution are summarized here.

". . . Whereas, the Nitijela has recently learned that at least two members of the scientific advisory panel were originally recommended to the Marshall Islands in 1989 by a DOE scientist. . . Whereas the conclusions contained in the NWRS Summary Report are based to a large extent on interpretation, evaluation and adjustments of various factors by its authors; . . . Whereas, the Nitijela strongly disagrees with the conclusion of the Summary Report that "radiation illness is. . . very rare, even among Marshallese. . .", Recognizing that the Nationwide Radiological Study does provide some practical and useful information, such as an indication of which atolls are presently dangerous for human habitation. . . Be it resolved by the people of the Republic of the Marshall Islands, . . . that the findings of the Nationwide Radiological Study as contained in the Summary Report. . . have not been accepted by the Republic as valid or accurate."

In a written response to the Nitijela, the Scientific Advisory Panel wrote: ". . . The scientists selected by the RMI Government to form the Scientific Advisory Panel are independent scientists chosen for their expertise in fields of health physics, radiation biology and radiation genetics. . . Rejection of the study's findings and the Summary Report is therefore a rejection of expert scientific knowledge on these matters. . . The

Nationwide Radiological Study has provided the Government of the Republic of the Marshall Islands and the Marshallese people with a comprehensive, soundly based survey of the radiological status of their islands. It would be deplorable if through ignorance and prejudice the results of the study were to be set aside. To do so would be to demonstrate that the RMI Government has no interest in seeking truth on these matters."

Nearly one year after the delivery of the Summary Report, the RMI Government requested the International Atomic Energy Agency (IAEA) to convene an international advisory group to review the radiological conditions of Bikini Atoll. In response, the IAEA appointed an advisory group that included scientists from Australia, France, Japan, New Zealand, Russia, UK, USA as well as from the WHO and IAEA. The advisory group met in December 1995 and following their review, they concluded: ". . . several in-depth studies on the radiological situation on and around the former [Marshall Islands] test sites were made. The US Government sponsored long term studies, and the Marshall Islands themselves financed a completely independent nationwide survey. . . This truly international scientific panel came, for one thing, to the conclusion that the existing data on the radiological situation were certainly correct. The studies, carried out independently of each other, had come to practically the same results."***

Despite these independent endorsements, the Nitijela to date has made no changes in its stand with respect to the findings of the NWRS.

In 1996, the people of Bikini memorialized 50 years of exile from their homeland. A dedicated effort was begun by the Bikini community to rehabilitate their atoll for community residence and a commercial dive operation was started to attract tourist trade income.

In September 1996, the Clinton Administration announced a \$45 million settlement with the Rongelap community to enable a resettlement of their atoll; the agreement provides for radiation mitigation and construction of homes, schools and other infrastructure.

On 19 December 1996, President Amata Kabua died. He was first elected president of the RMI and had been in office since 1979.

The Marshall Islands Nuclear Claims Tribunal reported that at the end of 1996, it had approved 1,297 compensation awards for personal injury claims. The awards totaled \$50.9 million, \$5 million more than the \$45 million it is to receive for distribution from the COFA. The Nuclear Claims Tribunal projected a liability of \$100 million in personal injury claims by the year 2001 when the COFA expires (Johnson 1997).

In early 1997, the Enewetak community filed a claim with the Nuclear Claims Tribunal for close to \$300 million for losses on the use of their atoll since 1947 when they were relocated to make way for the nuclear testing program (Johnson 1997).

*** unpublished letter of Advisory Committee to the IAEA Director General, January 1996.

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Author's note: Any inaccuracy in the events or documents related here are my own responsibility and are a likely result of my attempt to piece together the history from a variety of sources and sometimes confusing or barely legible documents. Similarly, any omission of significant persons, publications or events are my responsibility but have occurred only out of my ignorance and not of deliberate disregard.

REFERENCES

- Advisory Committee on Human Radiation Experiments. Final Report. Pittsburgh, PA: U.S. Government Printing Office; 1995.
- Adams, W. H.; Harper, J. A.; Rittmaster, R. S.; Heotis, P. M.; Scott, W. A. Medical status of Marshallese accidentally exposed to 1954 BRAVO fallout radiation: January 1980 through December 1982. Upton, NY: Brookhaven National Laboratory; BNL-51761; 1982.
- Atomic Energy Commission. Radioactive contamination of certain areas in Pacific Ocean from nuclear tests, a summary of the data from the radiological surveys and medical examinations. G. M. Dunning, Ed. Washington, DC: United States Atomic Energy Commission; 1957.
- Atomic Energy Commission. Press release L-191, Report of the Ad Hoc Committee to Evaluate the Radiological Hazards of Resettlement of Bikini Atoll. Washington, D.C.: U.S. Atomic Energy Commission; 12 August 1968.
- Atomic Energy Commission. Summary report of the 1969 and 1970 Bikini Surveys. Las Vegas, NV: United States Atomic Energy Commission, Nevada Operations Office; NVO-97; 1971.
- Bailey, C. Department of Defense, Radiation Experiments Command Center to David Saumweber, Advisory Committee on Human Radiation Experiments (ACHRE) Staff; 14 July 1995.
- Beck, H. L.; Bettett, B. G.; McCraw, T. F. External radiation levels on Bikini Atoll—May, 1967. New York: Health and Safety Laboratory, New York Operations Office, United States Atomic Energy Commission; HASL-190; 1967.
- Bellwood, P. Man's conquest of the Pacific Oxford: Oxford University Press; 1979.
- Bulletin of the Institute for Chemical Research, Kyoto University. Supplementary issue: The radioactive dust from the nuclear detonation. Kyoto: Institute for Chemical Research in collaboration with The Radioisotope Research Committee, Kyoto University; 1954.
- Biddulph, S. F.; Biddulph, O. A description of tumors on Ipomoea Tuba from the a-bomb test sites on Eniwetok Atoll. Seattle, WA: Applied Fisheries Laboratory, University of Washington; UWFL-23; 1953.
- Bond, V. P.; Conard, R. A.; Robertson, J. S.; Weden, J. E. A. Medical examination of Rongelap people six months after exposure to fallout. Bethesda, MD: Naval Medical Research Institute; San Francisco, CA: U.S. Naval Radiological Defense Laboratory; WT-937; Operation Castle—Addendum Report Project 4.1A; 1955.
- Bramlitt, E. T. Plutonium mining for cleanup. Health Phys. 55:451–453; 1988.
- Breslin, A. J.; Cassidy, M. E. Radioactive debris from Operation Castle, Islands of the Mid-Pacific. New York: U.S. Atomic Energy Commission, New York Operations Office, Health and Safety Laboratory; NYO-4623 (Del.); 1955.
- Chakravarti, D.; Held, E. E. Potassium and cesium-137 in Birgus Latro (coconut crab) muscle collected at Rongelap Atoll. Seattle, WA: Laboratory of Radiation Biology, University of Washington; UFWL-64 Biology and Medicine; 1960.
- Chakravarti, D.; Held, E. E. Chemical and radiochemical composition of the Rongelapese diet. J. Food Sci. 28:221–228; 1963.
- Conard, R. A. Acute myelogenous leukemia following fallout radiation exposure. J. Am. Med. Assoc. 232(13):1356–1357 1975.
- Conard, R. A.; Rall, J. E.; Sutow, W. W. Thyroid nodules as a late sequela of radioactive fallout. New England J. Med. 274:1392–1399; 1966.
- Congress, U.S. Radiation exposure from Pacific nuclear tests. Washington, DC: Subcommittee on Oversight and Investigations, Committee on Natural Resources, House of Representatives; Serial No. 103-68; 1994.
- Cronkite, E. P.; Bond, V. P.; Conard, R. A.; Shulman, N. R.; Farr, R. S.; Cohn, S. H.; Dunham, C. L.; Browning, L. E. Response of human beings accidentally exposed to significant fallout radiation. J. Am. Med. Assoc. 159:430–434; 1955.
- Davis, J. Bombing Bikini again (This time with money). New York Times Magazine 43–48, 68, 72–73; 1994.
- Deines, A. C.; Goldman, D. I.; Harris, R. R.; Kells, L. J. Marshall Islands chronology 1944 to 1990. Draft. Available from History Associates Incorporated, The Historic Montrose School, 5721 Randolph Road, Rockville, MD 20852; 1991.
- Delgado, J. P.; Lenihan, D. J.; Murph, L. E. The Archaeology of the atomic bomb: a submerged cultural resources assessment of the sunken fleet of Operation Crossroads at Bikini and Kwajalein lagoons. Sante Fe, NM: Submerged Cultural Resources Unit, National Park Service, Department of the Interior. Report No. 37; 1991.
- Defense Nuclear Agency. Operation Castle, Radiological Safety, Final Report, Volume I. Washington, D.C.: Defense Nuclear Agency; 1954a.
- Defense Nuclear Agency. Operation Castle, Radiological Safety, Final Report, Volume II. Washington, D.C.: Defense Nuclear Agency; 1954b.
- Defense Nuclear Agency. Compilation of local fallout data from test detonations 1945–1962 extracted from DASA 1251. Washington, D.C.: Defense Nuclear Agency; DNA 1251-2-EX; 1979.
- Department of Energy. The meaning of radiation at Bikini Atoll. Las Vegas, NV: U.S. Department of Energy; 1982a.

- Department of Energy. Melelen radiation Ilo Ailin koi Ituion Ilo Major, ko Rar Etali Ilo 1978 (The meaning of radiation for those Atolls in the northern part of the Marshall Islands that were surveyed in 1978). Las Vegas, NV: U.S. Department of Energy; 1982b.
- Department of Energy. Talleab in jet melele ko kin Enjebi (Enjebi information summary). Las Vegas, NV: U.S. Department of Energy, Nevada Operations Office; 1989.
- Department of Energy. DOE news. Energy Secretary unveils openness initiative. Washington, DC: U.S. Department of Energy; R-93-354; 1993.
- Department of Energy. United States nuclear tests July 1945 through September 1992. Springfield, VA: National Technical Information Service; DOE/NV-209 (Rev. 14); 1994.
- Donaldson, L. R. Radiobiological resurvey of Bikini Atoll during the summer of 1947. Seattle, WA: Applied Fisheries Laboratory, University of Washington; UWFL-7; 1947.
- Donaldson, L. R. Eniwetok radiological resurvey July 1948. Seattle, WA: Applied Fisheries Laboratory, University of Washington; UWFL-19; 1949.
- Donaldson, L. R. A radiological study of Rongelap Atoll, Marshall Islands, during 1954–1955. Seattle, WA: Applied Fisheries Laboratory, University of Washington; UWFL-42; 1955.
- Donaldson, L. R.; Held, E. E.; Olson, P. R. Radiation levels in biological samples collected at Ponape, Caroline Islands December 15–16, 1954. Seattle, WA: Applied Fisheries Laboratory, University of Washington; UWFL-40; 1955.
- Eisenbud, M. Memorandum to John C. Bugher, Director, AEC Division of Biology and Medicine; 29 July 1953a. Available from the Coordination and Information Center, Reynolds Electrical and Engineering Co., Las Vegas, NV.
- Eisenbud, M. Radioactive debris from Operation Ivy. New York: U.S. Atomic Energy Commission, New York Operations Office, Health and Safety Laboratory; NYO-4522 (Del.) 1953b.
- Eisenbud, M. An environmental odyssey: People, pollution, and politics in the life of a practical scientist. Seattle, WA: University of Washington Press; 1990.
- Eisenbud, M. Monitoring Distant Fallout: The Role of the Atomic Energy Commission Health and Safety Laboratory during the Pacific tests, with special attention to the events following Bravo. *Health Phys.* 71:21–28; 1997.
- Environmental Protection Agency. Transuranium elements. Volume 1. Elements of radiation protection. Washington, DC: U.S. Environmental Protection Agency; EPA 520/1-90-015; 1990a.
- Environmental Protection Agency. Transuranium elements. Volume 2. Technical basis for remedial actions. Washington, DC: U.S. Environmental Protection Agency; EPA 520/1-90-016; 1990b.
- Federal Radiation Council. Pathological effects of thyroid irradiation. Washington, DC: Federal Radiation Council; 1962.
- Federal Radiation Council. Pathological effects of thyroid irradiation. Washington, DC: Federal Radiation Council; 1966.
- Gessell, S. P.; Walker, R. B. Studies of soils and plants in the Northern Marshall Islands. *Atoll Research Bulletin*. Washington, DC: National Museum of Natural History, Smithsonian Institution, Nos. 355–364 (40th Anniversary Issue); 1–70; 1992.
- Gminder, R. Memorandum. Calculated radiation dose for an individual on Kwajalein Atoll following SANDSTONE/YOKE. Defense Nuclear Agency, Biomedical Advisor; 1981.
- Greenhouse, N. A. Memorandum to T. F. McCraw; Upton, N.Y.: Brookhaven National Laboratory; 19 July, 1978.
- Hamilton, T. E.; van Belle, G.; LoGerfo, J. P. Thyroid neoplasia in Marshall Islanders exposed to nuclear fallout. *J. Am. Med. Assoc.* 258:629–636; 1987.
- Harley, J. H.; Hallden, N. A.; Ong, L. D. Summary of gummed film results through December, 1959. New York: U.S. Atomic Energy Commission, New York Operations Office, Health and Safety Laboratory; HASL-93, UC 41, Health and Safety, TID-4500; 1960.
- Held, E. E. Gamma dose rates at Rongelap Atoll, 1954–1963. Seattle, WA: Laboratory of Radiation Biology, University of Washington; UWFL-91 Biology and Medicine (TID-4500); 1965.
- Held, E. E.; Gessel, S. P.; Walker, R. B. Atoll soil types in relation to the distribution of fallout radionuclides. Seattle, WA: Laboratory of Radiation Biology, University of Washington; UWFL-92 (Biology and Medicine TID-4500, 50th Ed.); 1965.
- Hicks, H. G. Results of calculations of external gamma radiation exposure rates from local fallout and the related radionuclide compositions of selected U.S. Pacific events. Livermore, CA: Lawrence Livermore National Laboratory; UCRL-53505; 1984.
- Hines, N. O. Proving Ground: An account of the radiobiological studies in the Pacific, 1946–1961. Seattle, WA: University of Washington Press; 1962.
- House, R. A. Memorandum for Record, from Headquarters Joint Task Force Seven; 1954. Available from the Coordination and Information Center, Reynolds Electrical and Engineering Co., Las Vegas, NV.
- Howard, J. E.; Heotis, P. M.; Scott, W. A.; Adams, W. H. Medical status of Marshallese accidentally exposed to 1954 BRAVO fallout radiation: January 1988 through December 1991. Upton, NY: Brookhaven National Laboratory; Report DOE/EH-0493; 1995.
- Hubert, L. F.; Machta, L.; List, R. J. A meteorological analysis of the transport of debris from operation ivy. Washington, D.C. United States Atomic Energy Commission; CIC-39684; 1953.
- Japan Society for the Promotion of Science. Research in the effects and influences of the nuclear bomb test explosions. Ueno, Tokyo: Japan Society for the Promotion of Science; Volumes I, II; 1956.
- Johnson, Giff. US State says it has fully settled Marshalls claims. *Mariana Variety*. 4 February 1997.
- King, M. Death of the Rainbow Warrior. Auckland, NZ: Penguin Books; 1986.
- Klemm, J.; Goetz, J.; Phillips, J.; Thomas, C. Analysis of radiation exposure, service personnel on Rongerik Atoll, Operation Castle, Shote BRAVO. McLean, VA Science Applications International Corporation; SAIC-86/1608; 1986.
- Kohn, H. I. Report. Rongelap Reassessment Project. Berkeley, CA: Rongelap Reassessment Project; 1988.
- Kohn, H. I. Report. Rongelap Reassessment Project. Berkeley, CA: Rongelap Reassessment Project; 1989a.
- Kohn, H. I. Report. Rongelap Reassessment Project, corrected edition. Berkeley, CA: Rongelap Reassessment Project; 1989b.
- Lessard, E. T.; Greenhouse, N. A.; Miltenberger, R. P. A reconstruction of chronic dose equivalents for Rongelap and Utrik residents—1954 to 1980. Upton, NY: Brookhaven National Laboratory; BNL5125/UC-41 (Health and Safety TIC-4500); 1980.
- Lessard, E.; Miltenberger, R.; Conard, R.; Musolino, S.; Naidu, J.; Moorthy, A.; Schopfer, C. Thyroid absorbed dose for

- people at Rongelap, Utirik and Sifo on March 1, 1954. Upton, NY: Brookhaven National Laboratory, Safety and Environmental Protection Division; BNL-51882, UC-48; 1985.
- Lulejian, N. M. Radioactive fall-out from atomic bombs. Baltimore, MD: Headquarters, Air Research and Development Command; C3-36417; 1953.
- Lynch, D. E. Radioactive debris from Operation Castle: World-wide fallout. New York: New York Operations Office, U.S. Atomic Energy Commission, Health and Safety Laboratory; NYOO 4621 (Del.); 1955.
- McCraw, T. F. Levels of environmental radioactivity in Bikini Atoll. Washington, DC: USAEC; WASH-1289; n.d.
- Micronesia Support Committee. Marshall Islands, a chronology: 1944–1981. Honolulu, HI: Micronesia Support Committee; 1978.
- Mwekto, W.; Anjain, J. Letter from Mayor W. Mwekto and Senator J. Anjain to Dr. Henry Kohn, Chairman of the Rongelap Reassessment Project. 27 July 1988.
- Neidenthal, J. A History of the People of Bikini following Nuclear Weapons Testing in the Marshall Islands: with recollections and views of elders of Bikini Atoll. 73: 28–36; 1997. Associated Press. 264 exposed to atom radiation after nuclear blast in Pacific. NY Times, 12 March 1954: 1.
- New York Times. Text of statement and comments by Strauss on hydrogen bomb test in the Pacific. New York Times 1 April; 1954: 1; 20.
- Nitijela, P. L. 1995-141 (Bill No. 232). Majuro, Marshall Islands: Nitijela of the Marshall Islands; 1995.
- North, D. Cashing in on nuclear waste. Pacific Islands Monthly 65(6): 11–13; 1994.
- Noshkin, V.; Robison, W. L.; Wong, K. M. Concentration of ^{210}Po and ^{210}Pb in the diet of Marshallese. Sci. Tot. Environ. 155:87–104; 1994.
- National Research Council. Radiological assessments for resettlement of Rongelap in the Republic of the Marshall Islands. Washington, DC: National Research Council, National Academy Press; 1994.
- P&D Technologies. Recommended phase 2 work plan for a comprehensive independent radiation study of Rongelap Atoll. Phoenix, AZ: P&D Technologies; 1989.
- Palumbo, R. F. Radioactivity and recovery of the land plants at Eniwetok Atoll, 1954–1957. Seattle, WA: Laboratory of Radiation Biology, University of Washington; UWFL-66; 1960.
- Parrot, Lindesay. Japan gets radioactive fish-Nuclear down-pour hit ship during test at Bikini-U.S. inquiry asked. NY Times, 17 March 1954:1.
- Rashid, Y. Commercial sense or sheer madness. Pacific Islands Monthly 65(6):15–16; 1995.
- Republic of the Marshall Islands. Marshall Islands revised code, Title 42, Chapter 1. Public Laws 19897-24, 1988-19, 1989-57 and 1990-101. Majuro, Marshall Islands: Republic of the Marshall Islands; 1987.
- Robison, W. L.; Conrado, C. L.; Phillips, W. A. Enjebi Island dose assessment. Livermore, CA: Lawrence Livermore National Laboratory; UCRL-53805; 1987.
- Robison, W. L.; Mount, M. E.; Phillips, W. A.; Conrado, C. L.; Stuart, M. L.; Stoker, C. E. The Northern Marshall Islands radiological survey: Terrestrial food chain and total doses. Livermore, CA: Lawrence Livermore National Laboratory; UCRL-52853, Pt. 4; 1982a.
- Robison, W. L.; Mount, M. E.; Phillips, W. A.; Stuart, M. L.; Thompson, S. E. An updated radiological dose assessment of Bikini and Eneu Islands at Bikini Atoll. Livermore, CA: Lawrence Livermore Laboratory; UCRL-53225; 1982b.
- Robison, W. L.; Phillips, W. A. Estimates of the radiological dose from ingestion of ^{137}Cs and ^{90}Sr to infants, children, and adults in the Marshall Islands. Livermore, CA: Lawrence Livermore National Laboratory; UCRL-53917; 1989.
- Robison, W. L.; Phillips, W. A.; Colsher, C. S. Dose assessment at Bikini Atoll. Livermore, CA: Lawrence Livermore National Laboratory; UCRL-51879, Pt. 5; 1977.
- Schultz, V.; Schultz, C. Bikini, Enewetak, Rongelap Marshall-ese; United States nuclear weapons testing in the Marshall Islands. Livermore, CA: Lawrence Livermore National Laboratory; UCRL-ID-105719, Rev. 1; 1991.
- Seaborg, G. T.; Loveland, W. D. The elements beyond uranium. New York: John Wiley & Sons, Inc.; 1990.
- Servis, J. Memorandum to G. M. Dunning, Task Group 7.1. 29 July 1954. Available from the Coordination and Information Center, Reynolds Electrical and Engineering Co., Las Vegas, NV.
- Sharp, R.; Chapman, W. H. Exposure of Marshall Islanders and American military personnel to fallout. Operation Castle-Project 4.1 Addendum, Report to the Scientific Director, Bethesda, MD: Naval Medical Research Institute WT-938; March 1957.
- Simon, S. L.; Graham, J. C. Findings of the Nationwide Radiological Study—Report to the Cabinet. Majuro, Marshall Islands: RMI Nationwide Radiological Study; 1994.
- Scientific Management Team. Executive summary: Rongelap Resettlement Project, Report of First Phase: Determining compliance with agreed limits for total annual dose-rate on Rongelap Island and actinide concentration of soils on Rongelap Islands and neighbouring islands. Majuro, Marshall Islands: Rongelap Resettlement Project; 1995.
- Scientific Management Team. Rongelap Resettlement Project scientific studies and Report of First Phase: Determining compliance with agreed limits for total annual dose-rate on Rongelap Island and actinide contamination of soils on Rongelap Island and neighbouring islands. Majuro, Marshall Islands: Rongelap Resettlement Project; 1994.
- Stannard, J. N. Radioactivity and health, a history. Columbus, OH: Battelle Press; DOE/RL/01830-T59 (DE88013791); 1988.
- Strauss, L. L. The truth about radioactive fall-out. U.S. News & World Report 25:35–38; 1955.
- Takahashi, T.; Trott, K. R.; Fujimori, K.; Simon, S. L.; Ohtomo, H.; Nakashima, N.; Takaya, K.; Kimura, N.; Satomi, S.; Schoemaker, M. J. An Investigation into the Prevalence of thyroid disease on Kwajalein Atoll, Marshall Islands. Health Phys. 73:199–213, 1997.
- Tipton, W. J.; Meibaum, R. A. An aerial and photographic survey of the eleven atolls and two islands within the northern Marshall Islands that were surveyed in 1978. Las Vegas, NV: EG&G Measurements Group, EG&G-1183-1758, UC-41; 1981.
- U.S. Statutes at Large. 78:601–602; 1964.
- U.S. Statutes at Large. 89:212; 1968.
- United States Department of Agriculture. Soil survey of the islands of Airik, Arno, Majuro, Mili and Taroa, Republic of the Marshall Islands. Washington, DC: United States Department of Agriculture, Soil Conservation Service; 1989.
- Weisgall, J. Operation Crossroads: The atomic tests at Bikini Atoll. Annapolis: Naval Institute Press, 1994.